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Metacommunity Dynamics of Gila River Fishes

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Metacommunity Dynamics of Gila River Fishes

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(1) Technical Proposal: Executive Summary.

Freshwater systems are critically imperiled and continue to be threatened by human encroachment and water development. The upper Gila River in New Mexico is one of the last unobstructed rivers in the Colorado River basin with a mostly intact native fish fauna, including two federally listed and one state-listed fish species. Understanding factors that allow persistence of native species faced with threats of predation by nonnatives, water development plans that would fragment habitats, and increased frequency and severity of disturbances associated with climate change will help reveal the consequences of those stressors. The proposed research uses a multi-scaled and synthetic approach in the upper Gila River system to quantify dispersal patterns, species interactions, and habitat attributes. This approach will test for the importance of these factors in shaping community dynamics of a unique and highly threatened fish fauna. Our approach uses a metacommunity framework that considers multiple communities of fishes in discrete habitats (reaches within tributaries or between tributary confluences) that are connected by dispersal. The overarching question addressed in the proposed research is: **How does habitat connectivity influence community dynamics (e.g., predation by nonnatives) and species persistence in arid-land stream networks?** To place this work in a broad evolutionary context, we emphasize variation in dispersal patterns and interspecific interactions among community members that represent three distinct life history strategies. By classifying species by their life history, we can test predicted dispersal patterns based on theory and broadly apply this knowledge to other species within or outside of the Gila River basin. For example, native and nonnative fishes in this system have very different life history strategies. Nonnative species (e.g., smallmouth bass and yellow bullhead) are typically apex predators with low fecundity but a relatively high degree of parental care. Native fishes are either opportunistic strategists with rapid population turnover rates or are large-bodied, highly fecund species, capable of migrating large distance and tracking resources over large spatial scales. If we find that dispersal dynamics of native and nonnative fishes can be predicted by life history strategy, this research will provide a general framework for conservation that considers how community interaction and responses to extreme events (e.g., those predicted by climate change) are influenced by fragmenting populations. By developing decisions support models, hosting workshops, and presenting our findings to regional stakeholder groups, we aim to provide conservation and water resource agencies critical information from which they can use to inform conservation plans.

The proposed project directly addresses Desert LCC funding priorities listed in Task Areas B and C. Specifically, in Task Area B (Projecting the resiliency and vulnerability of natural or cultural resources that affect or are affected by water resources management in a changing climate) our proposal will evaluate “the consequences of changes in habitat availability and connectivity” as well as “projecting changes to endangered species habitat distribution that may affect water releases and habitat improvement projects”. Within Task Area C (Assessing and evaluating natural or cultural resources management practices and adaptation opportunities), we propose to develop “methodologies or decision support tools to assess or evaluate current or existing resource management practices and the abilities to learn and adapt to the effects of climate change”.

(2) Technical Proposal: Technical Project Description.
(a) Describe the goal of the work in very specific terms.

A critical gap in stream conservation is that few empirical studies have applied a multi-scale approach to assessing the consequences and mechanisms of ecological processes occurring at the network scale (Fausch et al. 2002, Lowe et al. 2006). Measuring dispersal of stream organisms is particularly challenging and is often inferred by indirect methods that use variance partitioning to estimate the importance of dispersal based on patterns of spatial autocorrelation in species distributions or abundance (Cottenie 2005, Falke and Fausch 2010, Peres-Neto and Cumming 2010). Although informative, such methods are unable to control for factors that co-vary with species distributions, making it difficult or impossible, to distinguish among alternative hypotheses of community dynamics (Logue et al. 2011). Thus, direct quantification of connectivity (dispersal rates) among fragmented populations is necessary to validate predictions on long-term viability of stream communities. Our general understanding of stream community dynamics is further limited by a lack of information on patch dynamics, such as suitability of habitat patches as sources or sinks for dispersing individuals, how sources and sinks are distributed within larger networks of habitats, and the symmetry of dispersal (e.g., Dunning et al. 1992, Vuilleumier and Possingham 2006). Data necessary to quantify community dynamics in streams include dispersal patterns of community members, measures of patch quality, and knowledge of relevant interactions among species. Recent technical advances in genetic analyses and the use of chemical tracers facilitates measurements of dispersal and its relevance to population and community dynamics (e.g., Fraser et al. 2004, Woods et al. 2010, Winemiller et al. 2010, Gido and Jackson 2010). We propose a multi-scaled and synthetic approach in the upper Gila River system to test the relative importance of these factors in structuring a unique and imperiled fish fauna. The overarching question addressed in this proposal is: **How does habitat connectivity influence community dynamics and species persistence in stream networks?** Our **three main tasks are to: (1) Test the relative importance of dispersal factors, spatial factors, habitat, and biotic interactions on metacommunity dynamics; (2) Evaluate variation in dispersal patterns (tendency and symmetry) of species having three different life history strategies (opportunistic, periodic, and equilibrium strategists); and (3) Develop a predictive model for conservation of native fish communities in fragmented stream networks.** We will emphasize variation in dispersal patterns and life history traits among community members within a metacommunity framework. The metacommunity framework considers multiple communities on a landscape that are connected to by dispersal (Leibold et al. 2004). This approach is essential within stream networks because it acknowledges the importance of both local (e.g., predation, habitat selection) and regional (dispersal from source habitats) processes in regulating diversity and composition of communities. Our study will integrate ecological and genetic methods of estimating dispersal that span ecological and evolutionary time scales. Inclusion of representatives of different life history strategies will allow us to generalize our results to other systems because life history traits are generally strong predictors of the conservation status (e.g., Olden et al. 2006), invasiveness (e.g., Sakai et al. 2004), and sensitivity to fragmentation (Henle et al. 2004).

(b) Explain how the project should enhance the management of natural and cultural resources that affect or are affected by water resources management in a changing climate within the Desert LCC.

Conservation of the Colorado River Ecosystem – The Colorado River basin is renowned for its spectacular scenery and unique fauna. However, because of demands for its water, the Colorado River drainage is among the most controlled on Earth (Fradkin 1981). In addition to its role in sustaining human populations, this system is essential to maintenance of the region's endemic fauna and thus continental biodiversity (Minckley et al. 2003). Increasing human demands on the region's water resources continuously erode survival prospects for the aquatic fauna of the basin (Sabo et al. 2010). On average, ranges of extant native fish species have diminished more than 45% relative to their historical distribution, and 35% of these species have lost 50% or more of their range (Fagan et al. 2005). Concurrently, widespread introduction of nonnatives (Clarkson et al. 2005, Olden and Poff 2005, Propst et al. 2008) have compromised viability of native fish populations. Ongoing human-induced changes to the system, such as climate warming, water development, and species introductions further threaten persistence of its rivers and their inhabitants (e.g., Propst et al. 2008, Kennedy et al. 2009).

One exception to the highly engineered Colorado River system is the upper Gila River, which remains unimpounded and has a large proportion of its watershed in federally-protected lands. This system is one of the last strongholds for several rare fish species, including headwater chub *Gila nigra*, spikedace *Meda fulgida*, and loach minnow *Tiaroga cobitis*. Taking a metacommunity perspective as a means to understanding community persistence and gene flow is particularly useful in the upper Gila River system because the natural flow regime allows unimpeded physical connectivity among habitats (e.g., tributary branches and low gradient reaches separated by high gradient canyon reaches). Although physical attributes of the system have not been seriously altered since European settlement, it has been invaded by several nonnative fishes, with the numerically-dominant invaders, smallmouth bass *Micropterus dolomieui* and yellow bullhead *Ameiurus natalis*, functioning as top predators (Pilger et al. 2010). This combination of a naturally flowing system invaded by apex predators (native species are primarily insectivore/omnivores) provides an opportunity to assess how life history strategies, predator-prey dynamics, and dispersal patterns influence persistence of these highly sensitive communities.

Although native and nonnative fishes co-inhabit this system at the regional scale, persistence of native species at different locations within the upper Gila River drainage is highly variable and likely reflects patch dynamics (Propst et al. 2008, Stefferud et al. 2011). Specifically, long-term sampling at six sites over 20 years illustrated that native species persistence was variable across mainstem and tributary sites in the drainage, and this variability was associated with an interaction among physical characteristics of sites (i.e., temperature), annual variation in flows, and presence of nonnative fishes (Stefferud et al. 2011). Mainstem sites had the greatest species richness and greatest persistence of native fishes (Propst et al. 2008). In addition, some species only occur in cool, headwater communities and are replaced by other warm-water fishes in lower reaches. Quantifying fish community dynamics of this system that integrates life history traits of species will enable construction of a theoretical, but empirically tested, framework necessary to provide guidelines for conservation of native assemblages and to demonstrate consequences of fragmenting communities at a landscape level. Moreover, the relatively low species richness and simple network configuration in arid streams (i.e., mainstem with relatively few tributary branches) will allow us to comprehensively survey communities within the stream network.

(c) Describe and discuss in detail the stages of the proposed project.

General description of methods:

Estimating connectivity of metacommunities within the Gila River – Three complementary approaches (Table 1) will be used to quantify dispersal of a minimum of six fish species that represent the range of variation in life history strategies of fishes in the Gila River basin: 1) multi-scale patch occupancy modeling, 2) otolith microchemistry, and 3) microsatellite genetic markers. Multi-scale patch occupancy modeling will be used to infer local colonization and extinction processes based on seasonal sampling of habitat patches over three years to encompass a range of environmental conditions that may influence metacommunity dynamics. Otolith microchemistry will provide a history of patch occupancy during early life stages of each species and provides direct estimates of dispersal rates through the stream network. Finally, microsatellite genetic markers will be used to evaluate dispersal and effective population size (N_e) at the catchment spatial scale and at long temporal scales (i.e., multiple generations). Combined, these methods will provide a measure of dispersal rates within stream networks at multiple temporal scales of resolution. A necessary complement of this quantification of dispersal will be reach-level measures of environmental conditions that are likely to influence community dynamics, including disturbance regime, resource availability, and predation by nonnative fishes.

Table 1. Response variables measured by three basic approaches used to infer metapopulation and metacommunity dynamics in the Gila River basin.

Response variable	Patch occupancy	Otolith microchemistry	Microsatellites
Population size	Density from field surveys	N/A	Contemporary and historical N_e
Colonization/Migration Rate	Change in occupancy over time	Proportion of migrants based on natal signature	Fraction of migrants via assignment tests and equilibrium models
Movement symmetry	N/A	Site of origin based on natal signature	Migration asymmetry via assignment tests, coalescent models
Extinction	Change in occupancy over time	N/A	N/A
Population turnover	Change in occupancy over time	Origin of migrants in previously unoccupied patches	N/A

Measures of dispersal will be used to quantify connectivity among 16 patches in the Gila River (Fig.1). We define a patch as either a tributary stream, or a section of stream between tributary confluences. This definition is consistent with network theory (Urban and Keitt 2001) in that we consider confluences (nodes) and tributaries (branches) as potential barriers to movement and natural break points between patches, and the delineation of patches is consistent with the spatial and temporal context of stream habitats and dispersal of fishes (Pringle et al. 1988). In addition, we consider canyon reaches and ephemeral reaches as impediments to dispersal because they have limited availability of optimal habitat for native fishes or high abundance of nonnative predators.

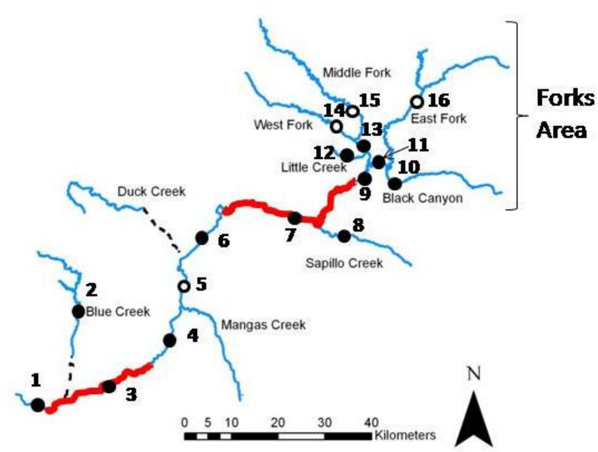

Figure 1. Map of the Gila River in New Mexico. Points represent proposed sampling locations for genetic tissues and otolith microchemistry. Open points indicate long-term monitoring sites. Reaches in bold red indicate canyons and dashed lines are ephemeral streams.

Below we describe the three methods of quantifying connectivity among sites and the temporal scale at which they measure dispersal. Then, we identify how information from these methods will be used to test our main research questions. Each method provides its specific insight into community dynamics, but together they offer a powerful approach that will allow us to characterize metapopulation and metacommunity dynamics for the Gila River system. These methods are complementary; for example, patch occupancy models can identify core and satellite populations but cannot evaluate the direction, magnitude, and life stage of fish movement that otolith microchemistry provides (Table 1). Likewise, genetic methods provide indirect estimates of population size and effective migration rates, but cannot be used to establish extinction rates and population turnover.

Patch occupancy modeling—To quantify probability of colonization and extinction, a multi-season single species (MacKenzie et al. 2003; MacKenzie et al. 2006). This approach relies on detection/nondetection data for species and size classes within each species that is collected across multiple patches (16 sites on Fig. 1) and multiple sampling seasons. Patches are open to colonization during intervals between sampling seasons, and an encounter history records the detection or nondetection of a species across patches and time. Given the different types of encounter histories across patches, a multinomial maximum likelihood function is then used to estimate the parameters of interest based on the frequency of different encounter histories. Using the initial occupancy parameterization in the program PRESENCE(version 3.1), colonization (γ_t) between season *t* and season *t+1* is estimated as a first order Markovian process (i.e. given a patch was unoccupied at season t, what is the probability the patch becomes occupied in season t +1). Other parameters estimated by this approach include probability of initial occupancy (ψ_1), and probability of extinction between season *t* and season *t*+1 (ε_t). Additional parameters of interest to metapopulation dynamics can be derived using this approach, including probability of occupancy at season *t*+1 (ψ_{t+1}), and rate of change in patch occupancy (λ_t).

Rate of change in patch occupancy is similar to a population growth rate, but measures whether patch occupancy is increasing or decreasing rather than population size. An occupancy modeling approach provides a quantitative estimate of dispersal across patches and among seasons within years and among years, in addition to generating static and dynamic rates that define metapopulation and metacommunity structure (patch occupancy, extinction probability, and rate of change in patch occupancy); and, if necessary, can be modified to account for imperfect detection. Furthermore, colonization, extinction, and patch occupancy can be modeled using both static (nonnative predator biomass at season *t*, and macroinvertebrate biomass at season *t*) and dynamic (mean daily discharge between season t and season t+1 and nonnative predator consumption between season *t* and season *t* + 1) site covariates, generating mechanistic explanations for the observed patterns, and yielding insight into the factors regulating the metapopulation and metacommunity. Moreover, this approach can be modified to incorporate multispecies (e.g., Dorazio et al. 2010), which considers the role of species interactions in determining patch dynamics.

Otolith microchemistry –Because otoliths reflect chemical composition of surrounding water, an analysis of their microchemical structure is a useful approach to determine natal origin of examined fish. Assuming fishes originate from locations with distinct water chemistry, natal origin is determined by comparing the chemical signatures from the outer edge of the otolith to that of the inner core area (Campana et al. 1995, Hobson 1999, Brazner et al. 2004, Woods et al. 2010). Geologic features of watersheds that influence water chemistry (e.g., age and chemical composition of parent material) as well as thermal regimes have been successfully associated with the chemical signature of otoliths in migratory and sedentary freshwater fishes (Seacor et al. 1995; Brazner et al. 2004, Barnett-Johnson et al. 2008, Whitledge 2009). Concentrations of Ca, Ba, Mg, Mn, and Sr, in addition to stable isotope ratios δSr ($^{87}Sr/^{86}Sr$), can distinguish origins of freshwater fishes among locations with variable water chemistry (Martinez et al. 2001, Brazner et al. 2004, Whitledge et al. 2007, Whitledge 2009).

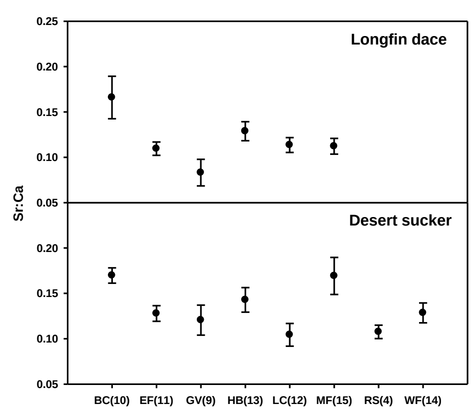

Figure 2. Sr:Ca ratios of the outer edge of otoliths taken from two species across 8 sites in the upper Gila River.

Acuña and Dahm (2007) identified distinct water chemistry differences among tributary streams of the Gila River that were linked to geologic features. Within the Forks area the West Fork (Site 14 in Fig. 1) is a cool stream (summer mean temperature = 18.0 ^{o}C) with distinctly low concentrations of Ca^{2+} (13.9 ± 4 mg/l), Middle Fork (Site 15) has thermal hot springs (summer mean temperature = 21.6 ^{o}C), and East Fork (Site 16) is intermediate in temperature and has distinctly high concentrations of Ca^{2+} (22 ± 2.1 mg/l)(Acuña and Dahm 2007). These differences in water chemistry among tributaries were reflected in the chemical composition of otoliths (edge only) from two species sampled from 8 of the proposed 16 sample sites in October 2010. Figure 2 provides an example of the variation in elemental ratios, and classification tree analysis of these data resulted in 92% and 85% classification success based on 4 elemental ratios (Sr:Ca, Mg:Ca, Ba:Ca, and Mn:Ca) and one isotope ratio δSr (Table 2).

We will determine the natal origins of juveniles of the six target species that are collected in autumn to quantify the probability and extent of dispersal of juveniles during a critical time period. A focus on juveniles will assure adequate numbers of individuals are available for analysis and will test the dispersal patterns of these early life stages of fishes, which is difficult to obtain otherwise. When possible, the same individuals taken for genetic samples will be examined for otolith microchemistry. Collections of ~30 individuals of each species at sites where they occur will be made in the first year of the study to evaluate the match between capture-site water chemistry and otolith chemical signature. Based on pilot data, otoliths will minimally be tested for ratios of Ba:Ca, Sr:Ca, Mg:Ca as well as δSr at their core (i.e., natal conditions) and edge (conditions at time of capture). Otolith preparation will follow (MacDonald et al. 2008) or a similar approach. Analysis will be run using a laser ablation inductively coupled plasma mass spectrometer (LA-ICPMS) in collaboration with Dr. Gwen Macpherson in the Department of Geology, University of Kansas. Inferences on dispersal will be based on classification analysis (e.g., classification trees, discriminant function analysis) that predicts origins based on multivariate chemical composition of otoliths matched with physical and chemical properties of the water. The metric of dispersal and dispersal symmetry will be based on the fraction of core signatures predicted to occur at other sites.

Table 2. Classification success of two fish species in 8 sites (numbers correspond to Fig. 3) of the Gila River basin based otolith microchemistry.

Site (map #)	Longfin dace	n	Desert sucker	n
Black canyon (6)	100%	5	80%	5
East Fork (11)	na		100%	5
Grapevine (9)	75%	4	80%	5
Heart bar (13)	100%	4	75%	4
Little Creek (12)	na		86%	7
Middle Fork (15)	75%	4	100%	4
Riverside (5)	100%	5	80%	5
West Fork (14)	100%	5	75%	4

Microsatellites– The goal of the comparative microsatellite analysis is to estimate the full migration matrix (**M**), a vector of population sizes ($\mathbf{N_e}$), and associated genetic diversity metrics such as heterozygosity and allelic richness for the six study species. Migration rates between sites *i* and *j* (m_{ij}) comprise the elements of **M** (where $m_{ij} \neq m_{ji}$) and are an estimate of the fraction of genotypes assigned as migrants at each locality. Effective population size (N_{ei}) measures the "temporary" linkage disequilibrium that arises due to inbreeding at the i^{th} locality and these values comprise the vector $\mathbf{N_e}$. The following computational approaches will be used to estimate **M** and $\mathbf{N_e}$ for each species. First, Approximate Bayesian Computation (ABC) procedures (e.g., BAYESASS [Wilson and Rannala 2003], BAPS [Corander et al. 2004], GENECLASS2 [Piry et al. 2004]) will provide snapshot estimates of m_{ij}, as well as allowing estimation of asymmetric migration (e.g., Fraser et al. 2007). In this proposal, we focus on contemporary estimates of genetic effective size that are obtained from linkage-disequilibrium methods, but this in no way precludes using other types of analysis (e.g., coalescent analysis of historical N_e via the program MIGRATE).

In 2010, fin clips (n > 1500) were collected from six target species at the proposed 16 sites (Fig. 1), although not all species are represented at every site. To date, nine microsatellite markers have been developed for four native species representing opportunistic and periodic life history strategies. Additional candidate loci are being optimized from closely-related species (Tranah et al. 2001, Turner et al. 2004, Cardall et al. 2007, Vu et al. 2005, Turner et al. 2009) and longfin dace. Species-specific microsatellite loci have been identified in previous work for nonnative yellow bullhead (Waldbiesera et al. 2001, Creer and Trexler 2006) and smallmouth bass (Malloy et al. 2001), both equilibrium strategists. Sampling targeted age-0 fishes to restrict genetic analyses to a single cohort in 2010, as such sampling greatly facilitates statistical estimation of $\mathbf{M}$ and $\mathbf{N_e}$ computed via the methods we propose (e.g., Waples and Do 2010).

High throughput microsatellite screening will be done in the Core Molecular Facility at UNM following routine protocols. GENESCAN software will be used to characterize microsatellite alleles in terms of size (in base pairs) and frequencies within and among sampling localities. All loci will be tested for null alleles, allelic dropout, and genotype scoring errors (Van Oosterhout et al. 2004). A series of reruns will be conducted to verify allelic identity across localities. Once data are quality checked and fully verified, standard analyses of allelic richness, heterozygosity, and pairwise and global estimates of F_{ST}, along with analyses described above will be accomplished.

Pilot data and approach to answer research questions and accomplish tasks

Below, we outline the three main tasks/research questions. We first present preliminary data that was collected to address the efficacy of our proposed research and to develop data-driven predictions that we can test with a full-scale project. After presenting those predictions, we identify how to use information from the three main approaches of measuring dispersal to accomplish our three main tasks.

Task 1: What is the relative importance of dispersal, spatial factors, habitat characteristics, and biotic interactions in determining metacommunity structure of fishes in the Gila River?

Preliminary data: Metacommunity theory considers trade-offs between species dispersal capabilities and their ability to coexist with other community members, and thus simultaneously considers factors structuring community members. Four models have been proposed to reflect the relative strengths of different structuring variables: neutral, species sorting, patch dynamics, and mass effects (Leibold et al. 2004). A neutral model suggests random associations of species within the river network and would be supported by weak covariance in population response vectors (e.g., $\mathbf{N_e}$, extinction rates, population size) among species and weak association with structuring variables (i.e., habitat quality and spatial predictors). Species sorting suggest communities are structured by environmental differences among sites and negative covariance would reflect differences in niche requirements among species. Mass effects would be supported if communities were spatially structured such that sites with the greatest colonization rates would have the largest population sizes and species diversity. Under this model, there would be moderate to high covariance among species that coexist at sites that receive large numbers of migrants (e.g., downstream). Patch dynamics would be supported if there was a tradeoff between dispersal ability and important biotic interactions (e.g., prey vulnerability). For example, species (and life stages) that are vulnerable to predation would have negative covariance with predators (nonnative, equilibrium species).

Long-term data on fish assemblages in the Upper Gila River (Propst et al. 2008, Stefferud et al. 2011) show that community structure and species persistence varies among tributaries and is associated with biotic (nonnative predators) and abiotic (temperature and stream size) factors, suggesting both source-sink and patch dynamics with limited dispersal among tributaries. Species diversity and persistence are greatest in lower mainstem sites relative to tributaries (Propst et al. 2008) suggesting mass effects and biased dispersal downstream or species sorting with unbiased dispersal but higher patch quality downstream. The general association between community structure and environmental factors in headwater streams (Falke and Fausch 2010, Brown and Swan 2010, Finn and Poff 2011) and increased diversity in the mainstem (Falke and Fausch 2010, Brown and Swan 2010) is consistent with other studies. However, a limitation of these studies is they do not directly quantify dispersal or the importance of biotic interactions. Comprehensive sampling of tributary populations and intensive measurements of habitat characteristics and predation pressure is necessary to fully consider factors structuring of these metacommunities and validate indirect measures of dispersal.

Predictions: (1) Canyon reaches that separate the upper (Forks) and lower (Cliff/Gila) Gila River drainage (Fig. 2) are a major structuring factor for all fish populations; 2) within these two regions, mainstem river metacommunities are spatially structured with increasing colonization downstream; 3) within tributaries, metacommunities are structured based on habitat and biotic interactions with minimal dispersal among tributaries; and 4) predation pressure (by equilibrium strategists) will be greatest in tributary sites with low productivity.

Data analysis: Response variables (Table 1) will be measured for at least two representative species from each life history group and will be analyzed as vectors that represent variation among sites (e.g., population size, genetic diversity, $\mathbf{N_e}$) or as matrices that represent relationships among the 16 sites (e.g., genetic distance, colonization sources, **M**). Relative importance of spatial, environmental, and biotic factors in predicting variation in population and community structure among sites will be based on variance partitioning of regression analysis for vector data (Legendre and Legendre 1998) and partial mantel or ordination methods for matrix data (e.g., Manel et al. 2003, Cottenie 2005, Peres-Neto et al. 2006, Peres-Neto and Cumming 2010, Mullen et al. 2010). Independent variables will include spatial, habitat, and biotic factors. <u>Spatial factors</u> will represent distances among sites as a vector (e.g., principal coordinates of neighbor matrices, Borcard and Legendre 2002) or distance matrix. Matrices that represent upstream or downstream movement bias (coded as dummy variables) will also be used as covariates to evaluate movement symmetry. <u>Habitat characteristics</u> will include: 1) Resource availability (estimated by measuring algal [chlorophyll a] and invertebrate biomass [surber and core samples], Whitney 2010) and 2) Hydrologic disturbance, monitored with HOBO water level and temperature loggers at each site to yield estimates of variability in discharge. The main biotic interaction we will consider is <u>Nonnative predation rates</u>, which will be evaluated through a bioenergetics approach (e.g., Johnson et al. 2008) based on estimated population sizes of predators, degree of piscivory, and temperature dependent metabolic rates of predators. The degree of piscivory will be estimated based on an ongoing food web study that has rigorously evaluated both diet and stable isotope data from fish communities at eight sites on the Gila River (Pilger et al. 2010). Estimates of consumptive demand will be generated by performing simulations using standard bioenergetics software (e.g., Fish Bioenergetics; Hanson et al. 1997).

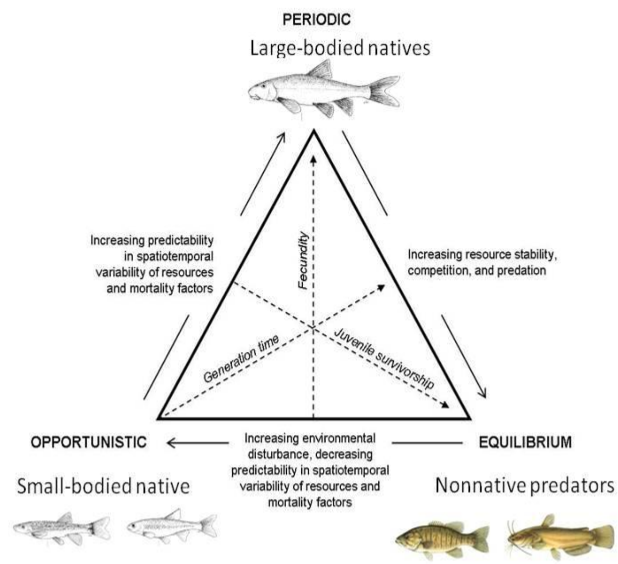

Figure 1. Conceptual diagram of life history tradeoffs of fishes based on Winemiller and Rose (1992). Illustrates the occurrence of native and nonnative fishes near extreme ends of this continuum. (Figure modified from Olden and Kennard, 2010).Native periodic species in the Gila River include Sonoran sucker, desert sucker and headwater chub; Native opportunistic species include spikedace, loach minnow, speckled dace and longfin dace; Nonnative equilibrium species include smallmouth bass, yellow bullhead, rainbow trout and brown trout (Olden et al. 2006).

Task 2: Can dispersal tendency be predicted based on life history traits?

Preliminary data: Fishes in the Gila River basin can be grouped into three distinct life history groups based on the trilateral continuum of Winemiller and Rose (1992) that evaluates tradeoffs among size at maturation, parental care, and fecundity (Fig. 3). Differences in age at maturity, fecundity, and parental investment are predicted based on life history theory to influence both dispersal and turnover rates. Life history theory also may be useful in predicting the suitability of habitats for species with different traits. For example, opportunistic and periodic species should favor habitats with high resource availability to sustain rapid growth (Winemiller and Rose 1992). Equilibrium species, however, are predicted to be efficient at monopolizing resources and should be favored in more stable habitats with lower resource availability. Because the Gila River exhibits a general increase in primary productivity moving downstream (Whitney 2010), we expect relative proportions of equilibrium, periodic, and opportunistic species to vary along this gradient.

Patch occupancy modeling of 6 sites along a gradient of stream size in the Gila River suggest differences in metapopulation structure among species representative of the three endpoints of the life history continuum; loach minnow (opportunistic), Sonoran sucker (periodic) and smallmouth bass (equilibrium). Using model selection to distinguish among competing models that incorporated different spatial and temporal scales, it was determined that loach minnow exhibited a hybrid metapopulation structure with patchy source populations in downstream reaches and sink populations upstream. This suggests downstream reaches supplement upstream sink reaches via dispersal. Downstream source patches also had lower nonnative predator biomass and higher algal and macroinvertebrate biomass (Whitney 2010), resulting in their greater patch quality for loach minnow. The low colonization probability for this opportunistic species (γ ranges from 0.04-0.14) confirmed predictions based on life history theory. Sonoran sucker demonstrated a patchy metapopulation structure across the entire basin, as a result of its high colonization probabilities, as predicted by life history theory. The high colonization probability exhibited by this species (γ=0.44) is consistent with our prediction for periodic life-history strategists. Smallmouth bass exhibited a nonequilibrium metapopulation structure across the entire basin, with low probabilities of colonization across sites (range in γ=0.08 to 0.17).

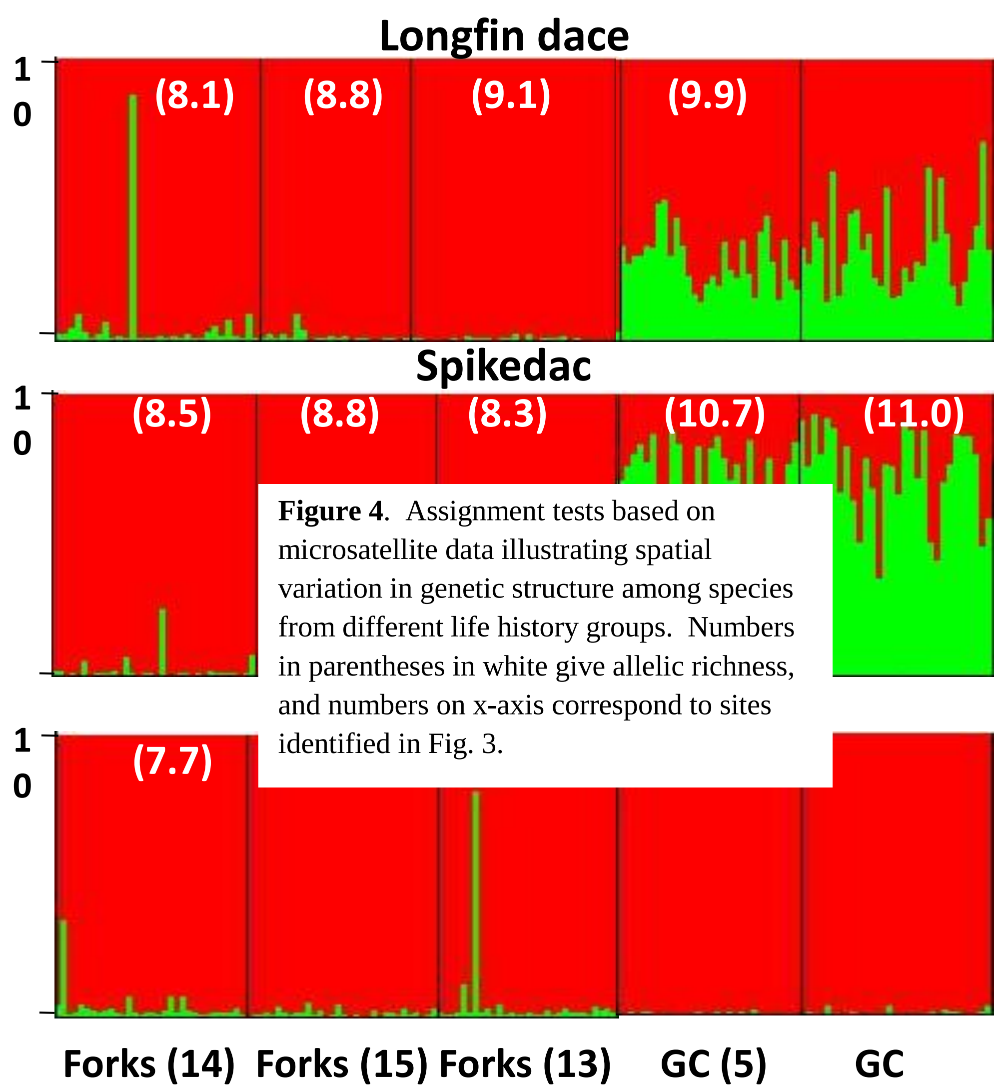

Figure 4. Assignment tests based on microsatellite data illustrating spatial variation in genetic structure among species from different life history groups. Numbers in parentheses in white give allelic richness, and numbers on x-axis correspond to sites identified in Fig. 3.

Preliminary genetic data from two opportunistic (spikedace and longfin dace) and one periodic (desert sucker) strategist are consistent with the hypothesis that dispersal patterns can be predicted by life history traits. Both opportunist species indicated distinct genetic structure between the Forks region and mainstem lower Gila River, whereas desert sucker had no detectable patterns across sites. Combined with measures of allelic richness, these data suggest populations of opportunistic species in headwaters (Forks region) are colonists from the larger population downstream (Fig. 4). The periodic species, which is predicted to disperse long distances, had a more homogeneous distribution across sites with upstream populations harboring higher levels of genetic diversity. Analysis of additional species and locations will provide a rigorous test of our hypotheses and yield a more comprehensive spatial structure in these populations.

Predictions: 1) Measures of dispersal (colonization) rates are greatest for periodic and least for equilibrium strategist, 2) turnover should be greatest for opportunistic species and least for equilibrium species, and 3) population size (absolute and N_e) should be greatest for periodic and opportunistic species, but will also increase in patches with the highest productivity and lowest predation.

Data analyses: A minimum of two species representing each endpoint life history strategy will be used to evaluate differences in the main response variables (Table 1) between populations of species with similar life history strategies and among species with different life history strategies. Colonization probabilities based on occupancy modeling, fraction of migrants (*m*) from assignment tests and ABC methods (as above), and otolith microchemistry will be compared among species to test *Prediction 1*. Turnover rates of populations based on occupancy modeling will be used to test *Prediction 2*. Regression analysis will be used to test the associations between densities and biomass of species from the different life history groups and measure of production to test *Prediction 3*. Multivariate analysis (e.g., PCA) will be used to synthesize covariance in the main response variables among species.

Task 3: Can a metacommunity perspective be used to develop a predictive framework for conservation of native fish communities in fragmented stream networks

The principles of metacommunity theory are thought to be particularly useful for understanding how the complex spatial structure of stream networks contributes to local and regional community dynamics (Brown et al. 2011). Because fragmentation and negative interactions with nonnative species are the leading causes of declines in native fishes in dryland rivers and elsewhere (Dudgeon et al. 2006, Propst et al. 2008, Jelks et al. 2008), conservation decisions must explicitly take these factors into account. We propose to develop a spatially-explicit conservation decision support tool that evaluates the persistence of desert fish metacommunities and their vulnerability to habitat fragmentation and nonnative species interactions. This approach will integrate knowledge gained through our study of desert fish metacommunity dynamics to identify at-risk habitats, assess the potential for management actions to affect those habitats, and anticipate the consequences for desert fish communities should prevailing conditions change. Specifically, we propose to use a belief network (BN; Reckhow 1999; Marcot 2006) approach to allow consideration of multiple, interacting factors (e.g., connectivity and biotic interactions) that influence persistence of desert fish metacommunities. The BN allows incorporation of information from multiple sources, including empirical data, expert opinion, and model output. Uncertainty resulting from any of those sources can be integrated directly into the BN, and carried through to the output to aid in management decision making. Moreover, the user-interface of a belief network is a logical and easy way to construct an influence diagram that is flexible and simple for the end user to manipulate. In our case, we plan to use knowledge gained through our investigation of desert fish metacommunity dynamics to parameterize the BN and allow the user to analyze trade-offs associated with connectivity and nonnative species (*sensu* Peterson et al. 2008). For example, the user could modify the placement of in-stream barriers (e.g., diversion structures or impoundments) and visualize the results on the probability of patch occupancy for multiple species. Likewise, if local factors are found to be more important drivers of community structure, management options such as habitat enhancement or nonnative removal could be manipulated within the BN and the results on patch occupancy assessed. Integrating metacommunity and life history theory into a decision support tool will provide a rigorous framework on which to base conservation and management actions.

Implications of Proposed Research for Water Development and Climate Change

Freshwater systems in the arid regions are critically imperiled and continue to be threatened by human encroachment, water development and climate change. The upper Gila River is one of the last unobstructed river systems in the Colorado River basin with a mostly intact native fish fauna. However, there are plans in place (e.g., the 2004 Arizona Water Settlements Act) that will allow additional development of Gila River water and impending climate change is likely to alter the distribution and connectivity of habitats within this system (e.g., Christensen and Lettenmaier 2007). The proposed study would provide critical information on which to build water use and conservation plans for this fragile and valuable ecosystem. Specifically, our ability to classify species with vastly different conservation status (e.g., threatened, stable, and nonnative) based on key life history traits, will aid in developing management strategies (Frimpong and Angermeier 2009). For example, both theory and empirical data show the ability of predators and prey to disperse among habitats is critical to the coexistence of predators and their prey (e.g., Resetarits 1995, Holt and Hoopes 2005). In the upper Gila River, top predators are equilibrium strategists, and are not predicted to be strong dispersers based on life history theory, thus native fishes may be able to escape predation by colonizing patches inaccessible to predators. Testing predictions such as this will help conservation agencies evaluate the efficacy of management efforts to control nonnative predators (e.g., construction of barriers and predator removals). Working closely with the state agency (see attached letters of support) will assure these findings are integrated into these policy decisions (Poff et al. 2003). To facilitate the use of our data by resource managers, we will present our findings and hold a 1-2 day workshop (describing the use of our BN) concurrent with the annual Natural History of the Gila symposium (http://gilasymposium.org) in autumn 2014.

Project time line

Date	Activities and relevant tasks
Spring and summer 2012	Quantify patch quality and patch occupancy; collect water chemistry and otoliths; analysis of existing genetic samples (**Tasks 1 and 2**)
Autumn 2012	Quantify patch quality and patch occupancy; collect water chemistry and otoliths (**Tasks 1 and 2**)
Winter 2012/2013	Laboratory analysis of otolith microchemistry; analyze occupancy data; analysis of genetic samples (**Tasks 1 and 2**)
Spring and summer 2013	Quantify patch quality and patch occupancy; analysis of genetic samples (**Tasks 1 and 2**)
Summer 2013	Develop decision support model (**Task 3**)
Fall 2013	Analysis of data; stakeholders meeting; prepare manuscripts (**Tasks 1,2 and 3**)

(d) Provide a specific discussion of the any anticipated problems or major difficulties in performing or accomplishing the work.

We acknowledge there are potential limitations to the use of otolith microchemistry. Some of the assumptions for this approach to work are outlined by Elsdon et al. (2008). Two limitation of particular concern are that to detect dispersal, fishes have to reside in an area long enough to obtain the chemical signature of that location, and chemical difference between sites has to be sufficient to detect differences. Although each of the 16 sites may not yield a unique chemical signature, pilot data suggest several sites will, and even partial data that quantifies movement among a subset of sites will help calibrate indirect measures of dispersal concurrently estimated via occupancy modeling and genetic analysis.

(e) Describe any prior studies that relate to the project or that will inform the project.

Much of our prior studies are listed above under 2.c. Of particular relation to this study is our long-term monitoring of fish communities in the upper Gila River basin. This collaborative work among several resource agencies has provided a strong baseline database on the interactions with a temporally dynamic flow regime and nonnative species (Propst et al. 2008, Stefferud et al. 2011). From these studies, we know that native species populations can fluctuate drastically at some sites and colonization from other locations is essential to maintain those populations. In addition to these long-term studies, we have extensive food web data based on diet and stable isotope analysis (Pilger et al. 2010). Our food web studies provide information on diet overlap and predator-prey relationships. This information allows us to formulate hypothesized interactions among species.

(f) Identify sources and support for non-Federal funding.

We will use two main sources of non-Federal funding to support this project:

1) PI Salary – Gido and Turner will contribute time during the academic year to this project and Propst will match his time consulting on the project.
2) Unrecovered overhead costs – KSU and UNM will route the proposal through the Cooperative Ecosystems Study Units with an indirect costs rate of 17.5%. The unrecovered indirect costs will be the difference in the standard amount based on the federal rate (48% at KSU and 51% at UNM) and will be used as cost share.

(3) Technical Proposal: Project Evaluation Criteria.

Subcriterion No. 1 – Project Scope:

See Technical Proposal

Subcriterion No. 2 – Ability to Accomplish Project Scope:

a. Describe the project team's ability to accomplish the project scope by including:

How will the budget be allocated to each of the tasks identified?

Budget will be administered through Kansas State University with will be responsible for patch occupancy and otolith microchemistry research. A subcontract to the University of New Mexico will support the genetics work and a subcontract to Dr. David Propst will support consultation on the research as well as the integration of research with resource managers. A subcontract will also be made to Dr. Jeffrey Falke to consult on the development of the decision support model.

Who are the members of the project team, and what tasks will each member perform?

Collection of specimens for genetic samples (fin clips) occurred in autumn 2010 (> 1,600 fin clips) and those samples are stored in an ultracold freezer and available for processing. Collection of otoliths for microchemistry analysis will be concurrent with field experiments. Analysis of genetic tissue will be supervised by Turner and the UNM graduate student and technician. Collection of otoliths will be the responsibility of Gido and KSU students. Preparation and processing of otoliths will be subcontracted to Dr. Gwen Macpherson in the Department of Geology at the University of Kansas. Dr. Macpherson's lab is equipped with a laser ablation multiple-collector ICP mass spectrophotometer. Field surveys (patch occupancy and habitat quality) will be supervised by Gido and Propst with the assistance of the KSU graduate and undergraduate students. Development of the decision support model will be supervised by Gido with consultation with Dr. Jeffrey Falke. Integration, data analysis and manuscript preparation will be a joint effort of PIs and graduate students.

What are the credentials of each of the project team members?

Gido is currently an Associate Professor at Kansas State University. He has a B.A. in Fisheries and Wildlife from New Mexico State University, a M.S. in the Division of Biology at the University of New Mexico and a PhD from the University of Oklahoma. Gido has conducted research in the Colorado River Basin for over 20 years. He has 65 peer-review publications, 13 of which report data on Colorado River basin fishes, and has recently edited a book title *Community Ecology of Stream Fishes: Concepts, Approaches, and Techniques*.

Propst is currently an Adjuct Professor in the Department of Biology at the University of New Mexico and Curatorial Associate at the Museum of Southwestern Biology. He recently retired from the New Mexico Department of Game and Fish after 26 years. Propst received a B.A. in Hisotry and Economics from Hampden-Sydney College, and a M.S. and PhD in Aquatic Biology from Colorado State University. He has over 50 peer-reviewed publications, numerous agency reports and invited presentations at national and international meetings.

Turner is currently a Professor of Biology and Director of the Museum of Southwestern Biology at the University of New Mexico. He has a B.S. and M.S. in Zoology from Ohio University and a PhD from Florida International University in Miami, Florida. Turner has conducted genetic analysis of fishes for 25 years and has focused primarily on ecological drivers of gene flow and effective population sizes in freshwater and marine fishes. He has over 50 peer-reviewed papers, that nearly all focus on genetics and ecology of aquatic systems, and has developed and grown museum-centered research and education programs.

Have the project team members accomplished projects similar in scope to that proposed in the past either as Principal Investigators or team members?

All PIs have extensive experience leading and participating in multidisciplinary project focused on the conservation of native fish communities. In the past 5 years, Gido has completed trophic studies of fishes in both the San Juan and Gila rivers (Gido et al. 2006, Franssen et al. 2007, Pilger et al. 2010) that were coordinated with larger multi-agency conservation and monitoring efforts. Propst has coordinated long-term monitoring programs on the San Juan (Propst and Gido 2004) and Gila River (Propst et al. 2008, Stefferud et al. 2011) as well as work in the Rio Grande, Pecos and Canadian rivers in New Mexico. Turner has served as PI and coordinated both food web (Pease et al. 2006, Turner et al. 2010) and comparative genetics studies on the Rio Grande that focus on the Rio Grande silvery minnow (Alò and Turner 2005, Turner et al. 2006, Osborne et al. 2010). He is currently co-PI on a BOR-funded project to study long-term genetic changes in razorback sucker stocks in Lake Mohave and Lake Mead in the Lower Colorado Basin (e.g., Turner et al. 2007, Turner et al. 2009).

Is the project team capable of proceeding with tasks within the proposed project immediately upon entering into a financial assistance agreement?

All PIs have ongoing projects in the proposed study area and have personnel in place (specifically one doctoral student at KSU and one at UNM) that will help initiate this research. Moreover, because we have already collected some data (i.e., fin clips for genetic analysis and otoliths for microchemistry analysis), we can begin that phase of the project immediately if funding becomes available.

b. Relevance of the Project to the LCC (30 points):

What is the geographic extent of the project? What is the relevance of the results of the project to a broader geographic area?

The propose work is focused on the upper Gila River basin in New Mexico. However, by testing the importance of dispersal from multiple species with different life history strategies, we are confident our work can be broadly applied to stream fish conservation elsewhere.

Does the project complement existing efforts within the geographic area of the LCC?

Recovery efforts for spikedace, loach minnow and Gila chub are ongoing in the upper Gila River basin. In particular, the Bureau of Reclamation is funding Gila chub habitat surveys to identify potential habitats for reintroduction efforts. Our proposed research will provide critical information on the importance on the importance of connectivity of habitats for Gila chub and other species that will be useful to inform decisions on relocation efforts.

The Gila River Basin Native Fishes Conservation Program (GRBNFCP) is a Bureau of Reclamation funded program associated with the Central Arizona Project to implement conservation strategies for federally protected fishes and to control or eliminate nonnative fishes. Specifically, within the upper Gila River basin there is currently a multi-agency effort to control nonnative species that is coordinated by the New Mexico Department of Game and Fish. The proposed project will be particularly useful for quantifying the ability of nonnative fishes to recolonize removal areas and to evaluate how those efforts will propagate throughout the stream network.

Finally, a recent agreement from participants of the GRBNFCP (USFWS, BOR, NMGF and AZGF, ex-officio are BLM and USFS) has approved the development of a basin-wide conservation plan. Our study will help define a hierarchal approach to defining conservation strategies for this system.

What is the expected benefit of the proposed project to partners within the LCC?

- *Will the proposed project benefit water management within the LCC? Will it benefit the management of other natural or cultural resources? Explain how.*

Results from our study will more clearly define the risks of different water management scenarios. For example, water management decisions for the Central Arizona Project, Arizona Water Settlement Act, and local irrigation management districts can be informed by our results. Moreover, predictions on habitat suitability and the ability of fishes to disperse under different climate change scenarios will be addressed in our research.

- *Will the results inform resource management actions immediately upon completion of the proposed project or will additional work be required?*

Yes, by working closely with resource agencies (see letters of support), results from our research will be immediately available if needed for conservation decisions. We also expect that our research will uncover other questions and gaps in knowledge that can be priorities for future research efforts.

- *Is there support for the proposed project from resource managers or other partners within the LCC (identify any partners or letters of support).*

See attached letters of support from the following scientists representing the various natural resource agencies within the Desert LCC region:

Martha Cooper, The Nature Conservancy

Kelly Russel/Jerry Monzingo, U.S. Forest Service
Andrew Monie, New Mexico Department of Game and Fish
Timothy Frey, U.S. Bureau of Land Management
Jim Brooks, U.S. Fish and Wildlife Service

c. Dissemination of Results (25 Points):

If spatially explicit data or tools are being developed, describe how this information will be made available to Geographic Information System platforms and provided to partners within the LCC.

At minimum, our point data on distribution of fishes, habitat suitability and population variability among sites will be available as shapefiles and associated attribute tables that will be readily available upon completion of the project. We are currently using a modified NHD stream layer as a basis for our research and will link appropriate data to the NHD stream layer.

Describe the anticipated number and type of peer reviewed scientific journal articles.

Results from the proposed research will contribute to two doctoral dissertations (one from KSU and one from UNM) that we expect to yield a minimum of 2 peer-reviewed journal articles each. In addition, we expect a minimum of 2 synthetic papers. In total, we expect a minimum of 6 peer reviewed scientific journal articles directly from this work.

Describe the number and type of presentations regarding the results of the project. For example, presentations at scientific conferences or presentations to resource managers within the LCC.

Members of this research team will present data at local (Gila Natural History Symposium), regional (Southwestern Association of Naturalist, AZ/NM AFS) and national (American Fisheries Society, Society of Freshwater Science [formally North American Benthological Society]) meetings. The PIs are also frequently asked to give invited talks at universities and other events that are likely to include data from the proposed work. Whereas resource managers are often present at the above-mentioned meetings, we also will hold a workshop associated with the Gila Natural History Symposium, to present our findings and discuss integration with policy decision making.

d. Connection to Reclamation Project Activities (5 points):

How is the project connected to Reclamation project activities?

See above (Central Arizona Project and Arizona Water Settlement Act)

Does the applicant receive Reclamation project water?

N/A

Is the project on Reclamation project lands or involving Reclamation facilities?

N/A

Is the project in the same basin as a Reclamation project or activity?

Yes, Reclamation has facilities in the lower Gila River basin.

Will the proposed work contribute water to a basin where a Reclamation project is located?

N/A

IV.D.5.f Performance Measure for Quantifying Actual Post-Project Benefits

N/A

IV.D.5.g Environmental and Regulatory Compliance

N/A

IV.D.5.h Required Permits or Approvals

In the application, applicants must state whether any permits or approvals are required and explain the plan for obtaining such permits or approvals.

Sampling of all species proposed in this study are covered by State of New Mexico Collecting Permits issued to each of the PI. No other permits are necessary for the proposed activities.

IV.D.5.i Funding Plan and Letters of Commitment

Letters of commitment:

See attached

Funding Plan:

(1) How you will make your contribution to the cost-share requirement (e.g., monetary and/or in-kind contributions) and the sources of funds you will contribute (e.g., reserve account, tax revenue, and/or assessments).

We will use two main sources of non-Federal funding to support this project:

1) PI Salary – Gido and Turner will contribute time during the academic year to this project and Propst will match his time consulting on the project.
2) Unrecovered overhead costs – KSU and UNM will route the proposal through the Cooperative Ecosystems Study Units with an indirect costs rate of 17.5%. The unrecovered indirect costs will be the difference in the standard amount based on the federal rate (48% at KSU and 51% at UNM) and will be used as cost share.

(2) Describe any in-kind costs incurred before the anticipated project start date that you seek to include as project costs. The description of these costs shall include:

N/A

(3) Provide the identity and amount of funding to be provided by funding partners as well as the required letters of commitment.

N/A

(4) Describe any funding requested or received from other Federal partners.

N/A

(5) Describe any pending funding requests that have not yet been approved and explain how the project will be affected if such funding is denied.

N/A

Please include the following chart to summarize your non-Federal and other Federal funding sources (table 2). Denote in-kind contributions with an asterisk Section IV Application and Submission Information 27

Summary of Non-Federal and Federal Funding Sources

Funding Sources	Funding Amount
1) Kansas State University	$114,557*
2) University of New Mexico	$55,961*
3) Dr. David Propst	$18,000*
Non-Federal Subtotal	$188,518
Other Federal Subtotal	$0
Requested Reclamation Funding:	$187,135
Total Project Funding:	$375,653

IV.D.5.j Letters of Project Support

The Nature Conservancy
Protecting nature. Preserving life.

Southwest New Mexico Field Office
P.O. Box 1603
Silver City, New Mexico 88062

Tel (575) 388-9700
Cell (575) 590-2594
Fax (505) 988-4095

nature.org/new mexico

25 July 2011

Keith Gido
Division of Biology
Kansas State University
Manhattan, KS 66506

Dear Dr. Gido,

Thank you for sharing a copy of your proposal "Metacommunity Dynamics of Gila River Fishes" (Principal Investigators K.B. Gido, D.L. Propst and T.F. Turner), that you intend to submit to US. Bureau of Reclamation's Desert Landscape Conservation Cooperative (LCC) program.

Freshwater systems are critically imperiled and continue to be threatened by human encroachment and water development. New Mexico's Gila River is one of the last free-flowing rivers in the U.S. Southwest. Its perennial waters support a diverse array of plants, animals, and natural communities. The Gila provides habitat for native desert fish that have disappeared from many other southwestern rivers. Endangered riparian and wetland communities are found along the Gila, including cottonwood-willow and sycamore forests.

The Gila River is one of the last unregulated rivers in the Colorado River basin with a largely intact native fish fauna, including two federally listed and on state-listed fish species. Understanding factors that allow persistence of native species faced with numerous threats will help land managers craft effective conservation strategies. Threats include predation by nonnatives, water development plans that would fragment habitats, existing water diversion and increased frequency and severity of disturbances associated with climate change.

The Nature Conservancy recognizes the importance of connectivity of habitats and interactions with nonnative species is of critical importance towards the conservation of fishes in the Gila River. For more than 25 years, The Nature Conservancy has collaborated with private landowners, mining companies, and public agencies including the US Forest Service, Bureau of Reclamation, US Fish and Wildlife Service and New Mexico Environment Department to devise creative, science-based solutions that conserve the Gila River. Currently The Nature Conservancy has funding from the New Mexico Department of Game and Fish for a long-term study documenting changes in fish habitat and surface/ground water dynamics.

Work by Dr. Gido and colleagues will amplify existing research efforts. I look forward to collaborating with the Principal Investigators on this project. The Nature Conservancy will contribute to the discussion of how their research can inform conservation management decisions.

Sincerely,

Martha S. Cooper

Martha S. Cooper
Southwest New Mexico Field Representative

USDA United States Department of Agriculture | Forest Service | Gila National Forest
Voice: 575.388.8201
Fax: 575.388.8204
TTD: 575.388.8489 | 3005 E. Camino del Bosque
Silver City, NM 88061-7863
Internet: www.fs.usda.gov/gila

File Code: 2600
Date: July 27, 2011

Keith B. Gido, Ph.D.
Division of Biology
Kansas State University
Manhattan, KS 66506

Dear Dr. Gido:

My staff has reviewed and support your proposal entitled "Metacommunity Dynamics of Gila River Fishes" (Principal Investigators K.B. Gido, D.L. Propst and T.F. Turner), that you intend to submit to US. Bureau of Reclamation's Desert Landscape Conservation Cooperative (LCC) program. The Gila National Forest recognizes that the importance of connectivity of habitats and interactions with nonnative species is of critical importance towards the conservation of fishes in the Gila River. Climate changes impact on water distribution, timing of precipitation, availability, storage, watershed management, and human water uses, may present some of the most important challenges of National Forest management in the Southwest.

The development of methodologies or decision support tools to assess or evaluate current or existing resource management practices and the abilities to learn and adapt to the effects of climate change will be important for future management of the Gila National Forest. This work will complement existing efforts by the Forest and you as our ongoing partners. We are pleased to collaborate with the Principal Investigators on this project. We are willing to provide advice to the investigators on how to integrate their research into the management and conservation decision making process.

Please contact Jerry Monzingo, Gila National Forest Fishery Biologist 575-388-8221 with any questions you may have.

Sincerely,

Kelly Russell

KELLY M. RUSSELL
Forest Supervisor

22 July 2011

Dr. Keith Gido
Division of Biology
Kansas State University
Manhattan, KS 66506

Dear Dr. Gido,

Thank you for the opportunity to read your proposal "Metacommunity Dynamics of Gila River Fishes" (Principal Investigators K.B. Gido, D.L. Propst and T.F. Turner), that you intend to submit to US. Bureau of Reclamation's Desert Landscape Conservation Cooperative (LCC) program. The Bureau of Land Management (BLM) recognizes that connectivity of habitats and interactions with nonnative species is of critical importance towards the conservation of fishes in the Gila River. This work will complement existing efforts by the BLM and we are excited to integrate your research into the land management and conservation decision making processes. Please keep us posted if there is anything we can do to further your study as it pertains to public lands and the BLM.

Sincerely,

//Tim Frey//

Tim Frey
Fisheries Biologist
Bureau of Land Management
Las Cruces District Office
Las Cruces, NM

GOVERNOR
Susana Martinez

DIRECTOR AND SECRETARY
TO THE COMMISSION
Tod W. Stevenson

STATE OF NEW MEXICO
DEPARTMENT OF GAME & FISH

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26 July 2011

Dr. Keith Gido
Division of Biology
Kansas State University
Manhattan, KS 66506

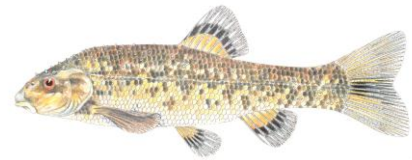
Dear Dr. Gido,

I just had the chance to read over your proposal "Metacommunity Dynamics of Gila River Fishes" (Principal Investigators K.B. Gido, D.L. Propst and T.F. Turner), that you intend to submit to US. Bureau of Reclamation's Desert Landscape Conservation Cooperative (LCC) program. The New Mexico Department of Game and Fish recognizes the importance of connectivity of habitats and interactions with nonnative species is of critical importance towards the conservation of native fishes in the Gila River. This work will better inform and help guide existing efforts by our agency and we are excited to collaborate with the Principal Investigators on this project. We are willing to provide advice to the investigators on how to integrate their research so as to accomplish the greatest impact toward our mutual conservation goals.

Sincerely,

Andrew Monié
Gila/Canadian Native Fish Biologist
New Mexico Department of Game and Fish
Conservation Services Division
Santa Fe, NM 87507

David Propst, Ph.D.



tiaroga@comcast.net

Paul Lowe
Assistant Vice President for Research
Director, PreAward Services
002 Fairchild Hall
Kansas State Univeristy
Manhattan, Kansas 66506

Thursday, 21 July 2011

Dear Mr. Lowe,

Please accept this letter as confirmation of my contributions and commitments as a consultant to "Metacommunity Dynamics of Gila River Fishes" (Principal Investigator Dr. Keith Gido), a study proposal submitted to US. Bureau of Reclamation's Desert Landscape Conservation Cooperative (LCC) program.

For this project, my specific responsibilities will include coordinating and supervising field data collection, especially that related to collection of specimens for life history characterization and otolith microchemistry, compiling data and data quality control, collaborating with other Principal Investigators on data analyses and drafting manuscripts based on results obtained, and coordinating activities with cooperating agencies.

My commitment to accomplish the tasks identified in the foregoing paragraph is 240 hours/year. For projects, such as this, my standard rate is $75.00/hour. My in-kind contribution will be 120 hours ($9,000.00); the project will not be billed for these hours. My total annual billing for the project will not exceed $9,000.00 (120 hours).

Should you have any questions, please contact me at the above address.

Sincerely yours,

David L. Propst

UNM | *Office of the Vice President for Research*

August 1, 2011

Carmen Garcia
Grant & Contract Administrator – Vice President for Research
Kansas State University
Carmen@ksu.edu
(785) 532-6804

Dear Ms Garcia

The Regents of the University of New Mexico and the Museum of Southwest Biology wish to participate as a proposed sub recipient in your application to the US Department of Interior/Bureau of Reclamation, "Metacommunity dynamics of Gila River fishes" under the direction of Dr. Thomas Turner.

The proposed total project cost for the University of New Mexico is $76,359.00 for the period of January 01, 2012 through December 31, 2013.

Should an award be made to Kansas State University, the Regents of the University of New Mexico are prepared to address suitable terms and conditions to enter into a negotiated agreement. Brenda Baker, Senior Contract and Grant Administrator, will be your point of contact and can be reached directly at 505-277-2341 or via email at brbaker@unm.edu.

Thank you for your consideration of this proposal.

Respectfully Submitted,

Tim Wester
Grants Coordinator
Pre-Award Services, Main
The University of New Mexico
(505) 277-8806
twester@unm.edu

36423

IV.D.5.k Official Resolution

Kansas State University Authorized Business Official:
Paul R. Lowe
Assistant Vice President for Research & Director of PreAward Services
2 Fairchild Hall
Manhattan, KS 66506-1103
Phone (785) 532-6310 Fax (785)532-5944
Email: plowe@ksu.edu.

IV.D.5.l Budget Proposal

Main Kansas State University Budget

Budget Item Description	$/unit and unit	Quantity	Recipient Funding	Reclamation Funding	Total Cost
SALARIES AND WAGES					
Keith Gido	**$8,208/mo**	**3.25 mo**	**36,936.00**	**16,416.00**	**53,352.00**
Technician	**$1,667/mo**	**6 mo**		**10,000.00**	**10,000.00**
FRINGE BENEFITS					
Keith Gido (35%)	**$2,873/mo**	**3.25 mo**	**12,928.00**	**5,746.00**	**18,674.00**
Technician (1.3%)	**$22/mo**	**6 mo**		**130.00**	**130.00**
TRAVEL					
From KS to field sites	**$4500/yr**	**2yr**		**9,000.00**	**9,000.00**
EQUIPMENT					
SUPPLIES/MATERIALS					
Field supplies	**$2500/yr**	**2yr**		**5,000.00**	**5,000.00**
Otolith microchemistry	**$12,500/yr**	**2yr**		**25,000.00**	**25,000.00**
Decision support modeling	**$5000/yr**	**1yr**		**5,000.00**	**5,000.00**
CONTRACTUAL					
Subcontract to UNM[1]	**Separate budget**		**55,961.00**	**76,342.00**	**132,303.00**
Consultancy with David Propst	**$9000/mo**	**4 mo**	**18,000.00**	**18,000.00**	**36,000.00**
ENVIRONMENTAL COMPLIANCE					
OTHER					
TOTAL DIRECT COSTS			**90,507.00**	**170,634.00**	**261,141.00**
INDIRECT COSTS			**98,011.00**	**16,501.00**	**114,512.00**
TOTAL PROJECT COSTS			**188,518.00**	**187,135.00**	**375,653.00**

University of New Mexico Subcontract Budget

Budget Item Description	$/unit and unit	Quantity	Recipient Funding	Reclamation Funding	Total Cost
SALARIES AND WAGES					
Tom Turner	**$9094/mo**	**2.945 mo**	**17,687.00**	**9,094.00**	**26,781.00**
RA	**$1700/mo**	**12 mo**		**20,706.00**	**20,706.00**
FRINGE BENEFITS					
Tom Turner (18.9%)	**$1,643/mo**	**2.99 mo**	**4,956.00**	**1,643.00**	**6,599.00**
RA (1%)	**$130/mo**	**12 mo**		**1,558.00**	**1,558.00**
TRAVEL					
From KS to field sites				**0.00**	**0.00**
EQUIPMENT					
SUPPLIES/MATERIALS					
Laboratory supplies	**$6,929/yr**	**2yr**		**13,859.00**	**13,859.00**
Molecular analysis	**$6,019/yr**	**2yr**		**12,037.00**	**12,037.00**
CONTRACTUAL					
ENVIRONMENTAL COMPLIANCE					
OTHER (Tuition and fees)	**$3045/semester**	**2 semesters**		**6,090.00**	**6,090.00**
TOTAL DIRECT COSTS			**22,643.00**	**64,987.00**	**87,630.00**
INDIRECT COSTS	**17.5% TDC**		**33,318.00**	**11,373.00**	**44,691.00**
TOTAL PROJECT COSTS			**55,961.00**	**76,360.00**	**132,321.00**

Budget Narrative

(a) *Salaries and Wages* – Funds from BOR are requested to support one month of Gido's and ½ month of Turner's salary during summer to free time to provide guidance during field and laboratory experiments. Propst will also be supported as a consultant to KSU to assist in field surveys and consultation with regional conservation agencies. The KSU technician will assist the currently funded KSU graduate student in collecting data and samples from study sites as well as to process samples in the laboratory when not in the field. The funded KSU graduate student will also prepare otoliths for sampling. The Research Assistant at UNM will work on developing markers and analysis of genetic tissues.

(b) *Fringe Benefits.* – Fringe rates are given in the table above.

(c) Travel. – Travel will offset the costs of travel from Kansas to New Mexico and travel among the 16 sample sites. We expect to travel 2,100 miles/trip x 3 trips per year x $0.5/mile = $3,150 for mileage. Meals and lodging for 3 people will be $450/trip x 3 trips = $1,350.

(d) Equipment – No equipment will be purchased for this project.

(e) Materials and Supplies – Basic field equipment and supplies requested in KSU budget will be required to conduct occupancy surveys at these sites. This will include electrofishing batteries, seine nets, dip nets, waders, tape measures, sample jars, and preservatives. Laboratory supplies requested in UNM subcontract will include sample vials, glassware, chemicals and reagents necessary for genetic work.

(f) Contractual – Salary will be provided to Dr. Propst to coordinate field activities (e.g., access to field sites, sampling protocols), participate in analysis and synthesis of data, and coordinate meetings with stakeholders to share information from the project. Salary will also be provided to Dr. Jeffery Falke, who has expertise in developing decision support models for conservation of aquatic systems.

(g) Environmental and Regulatory Compliance Costs – N/A

(h) Reporting – N/A

(i) Other – Subcontract to UNM requires tuition and fees for the Graduate Research Assistant.

(j) Indirect Costs – Funding to KSU and the subcontract to UNM will be routed through the Cooperative Ecosystem Study Unit program at an overhead rate of 17.5%. Unrecovered overhead and overhead on contributed salary and fringe benefits is counted as cost share.

(k) Contingency Costs – N/A

(l) Total Cost - $**375,653**

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